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UNITED STATES PATENT APPLICATION

FOR

**A PIVOT POINT ARM FOR A ROBOTIC SYSTEM USED TO PERFORM A
SURGICAL PROCEDURE**

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a pivot arm that can support a surgical instrument during a medical procedure.

5 2. Background Information

There have been developed surgical robots that assist surgeons in performing medical procedures. By way of example, the assignee of the present invention, Computer Motion, Inc. of Goleta, California sells a medical robotic arm under the trademark AESOP and a medical robotic system under the trademark ZEUS. The AESOP product includes a robotic arm that can be controlled through a foot pedal or voice commands from the surgeon. The AESOP arm is typically used to move an endoscope that is inserted into a patient during a laparoscopic procedure. The ZEUS system includes multiple robotic arms that can control surgical instrument used to perform minimally invasive procedures. The ZEUS robotic arms are controlled by handles that are manipulated by the surgeon.

Coronary artery bypass graft (CABG) procedures can be performed minimally invasively using the ZEUS and AESOP products. The surgical instruments and endoscope are inserted through small incisions created in the chest of the patient. The robotic arms include both active and passive joints that move the instruments and endoscope about corresponding pivot points. The pivot points are created by the incisions formed in the patient.

Some surgeons are uncomfortable performing minimally invasive CABG procedures and will only perform the procedure with an opened chest cavity. There may still be a desire to utilize robotic arms to control the instruments even during an open chest procedure. For example, the ZEUS system will filter the natural hand tremor of the surgeon.

There are no incisions or corresponding pivot points in an open chest procedure. Unfortunately, the ZEUS and AESOP systems will not function properly without the pivot points created by the incisions. It is therefore desirable to create a pivot point for the robotic arms to function during a non-minimally invasive procedure.

Computer motion has provided a support arm that could support an instrument during a non-minimally invasive procedure. The instrument could be inserted through a diaphragm located at the distal end of the arm. The
5 diaphragm provided some flexibility to pivot the instrument but not enough to allow sufficient movement by a robotic arm to perform most medical procedures.

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BRIEF SUMMARY OF THE INVENTION

One embodiment of the present invention includes a pivot port that has an adapter coupled to a pivot arm by a joint. Another embodiment includes a ball joint that is
5 coupled to a pivot arm.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of an embodiment of a medical system of the present invention;

Figure 2 is a perspective view of a pivot port of the

5 medical system;

Figure 3 is a perspective view of an alternate embodiment of the pivot port.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In general the present invention includes a pivot port that can provide a pivot point for a surgical instrument moved by a robotic arm. The pivot port may be held in a stationary position by a support arm assembly that is attached to a table. The pivot port may include either an adapter or a ball joint that can support the surgical instrument. The pivot port allows the instrument to pivot relative to a patient. The pivot arm allows the robotically controlled surgical instrument to be used in a non-minimally invasive procedure such as an open chest coronary artery bypass graft (CABG) procedure. Although use of the pivot arm in open chest CABG procedures is described, it is to be understood that the pivot arm can be used in other surgical procedures including minimally invasive procedures. For example, the pivot arm can be used to hold an instrument for a minimally invasive CABG procedure. Additionally, the pivot arm can hold instruments that are not robotically controlled.

Referring to the drawings more particularly by reference numbers, Figure 1 shows an embodiment of a

medical system 10 of the present invention. The system 10
may include a pivot port 12 that is held in a stationary
position by a support arm assembly 14. The support arm
assembly 14 may be attached to a surgical table (not
5 shown).

A surgical instrument 16 can be coupled to the pivot
port 12. The surgical instrument 16 can be coupled to a
robotic arm 18. The pivot port 12 is constructed so that
the instrument 16 can pivot relative to the arm 12 with a
sufficient range of motion so that medical procedures can
be performed with the robotic arm 18.

The robotic arm 18 may include a linear actuator 20, a
first rotary actuator 22 and a second rotary actuator 24
that are controlled by a computer (not shown) to move the
surgical instrument 16. The robotic arm 18 may also have
an end effector (not shown) to spin and/or actuate the
instrument 16. The arm 18 may also have passive joints
(not shown) that allow the instrument 16 to pivot about the
pivot port 12. The robotic arm 18 may be a product sold by
20 Computer Motion, Inc. of Goleta, California under the

trademark AESOP or a Computer Motion product sold under the trademark ZEUS, which are hereby incorporated by reference.

Figure 2 shows an embodiment of the pivot port 12. The pivot port 12 may include a first link 26 that is coupled to a pivot arm 28 by a first joint 30. The first link 26 may be coupled to a ring 32 by a second joint 34.

The pivot port 12 may include an adapter 36 that can be coupled to the ring 32. The surgical instrument 16 can extend through an aperture 38 of the adapter 36. The aperture 38 should have a diameter that allows the instrument 16 to spin and translate relative to the pivot port 12. The first 30 and second 34 joints allow the ring 32 and corresponding instrument to pivot about the arm 28 to provide yaw and pitch rotation.

The adapter 36 may have an outer annular flange 40 that rests on an inner annular lip 42 of the ring 32. The adapter 36 may be constructed to be readily attached and detached from the ring 32. This allows adapters having different aperture diameters to be inserted into the pivot port 10 to accommodate different instrument sizes.

Figure 3 shows an alternate embodiment of a pivot port 43 that includes a ball joint 44 that can pivot relative to a ring 45. The ring 45 is attached to a pivot arm 46. The ball joint 44 may have a plurality of apertures 48 that can receive a surgical instrument 16. The ball joint 42 allows the instrument 16 to pivot relative to the arm 46. Opposing pairs of apertures 48 can be constructed to have different diameters to receive instruments of different sizes. The ball joint 44 thus provides a joint that can accommodate different instrument sizes without having to replace the joint as may be required in the embodiment shown in Fig. 2.

Referring again to Fig. 1, support arm assembly 14 includes a support arm 50 that is coupled to a table mount 52. The table mount 52 is adapted to be secured to a surgical table (not shown). The support arm assembly 14 further includes an end effector 54 that is coupled to the arm 50. The end effector 54 is adapted to hold the pivot arm 28 or 46 of the pivot port 12, or 43, respectively.

The arm 50 may include a first linkage 56 that is coupled to the table mount 52 and a second linkage 58

coupled to the first linkage 56. The arm 50 may further have a third linkage 60 coupled to the second linkage 58.

The first linkage 56 may extend through a clearance hole (not shown) in a base 62 of the table mount 52. The table mount 52 may have an arm clamp 64 that can be rotated to engage the first linkage 56 and secure the position of the end effector 54 in a vertical direction. The arm clamp 64 can be rotated in an opposite direction to disengage the clamp 64 and allow an end user to move the first linkage 56 and adjust the height of the end effector 54 and pivot port.

The table mount base 24 may include a jaw section 66 that can clasp onto the rail of an operating table (not shown). The jaw section 66 can be secured to the table rail by a table clamp 68.

The second linkage 58 may be coupled to the first linkage 56 by a first ball joint 70. Likewise, the end effector 54 may be coupled to the third linkage 60 by a second ball joint 72. The third linkage 60 may be coupled to the second linkage 20 by a pivot joint 74. The ball joints 70 and 72, and pivot joint 74 provide the support

arm six degrees of freedom. The position of the arm 50 and
end effector 54 can be secured and locked in place by
rotating a locking knob 76. The locking knob 76 clamps the
pivot joint 74 to prevent relative movement between the
5 third 60 and second 58 linkages. Rotation of the locking
knob 76 also moves corresponding wedges (not shown) into
the ball joints 70 and 72 to secure and lock the second
linkage 58 and the end effector 54, respectively. The arm
50 and table mount 52 can be purchased from KARL STORZ
10 under part number 28172H. The end effector 54 may have a
spring biased retractable jaw 78 that can capture the pivot
port 12. The retractable jaw 78 allows an operator to
readily attach and detach the pivot port 12 to the support
arm assembly 14. The joints 70, 72 and 74 allow the
15 operator to adjust the pivot port 12 location and the
instrument 16.

The following medical procedure can be performed with
the pivot point 12 of the present invention. A patient's
chest cavity may be opened and the pivot port 12 may be
20 attached to the support arm assembly 14 adjacent to the
open chest cavity. A surgical instrument 16 may then be

inserted through the pivot port 12 and attached to the robotic arm 18. The robotic arm 18 may then be actuated to move the instrument 16 and perform a procedure. The pivot port 12 allows the instrument to pivot about the port 12.

- 5 When the procedure is completed, the instrument 16 may be decoupled from the robotic arm 18 and pulled out of the pivot port 12. The pivot port 12 may then be detached from the support arm assembly 14.

10 While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other
15 modifications may occur to those ordinarily skilled in the art. For example, although an open chest procedure is described, the pivot port can provide a pivot point for any type of medical procedure.